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UNIVERSITÄT FREIBURG

Algorithms for Radio Networks

Multiplexing

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Christian Schindelhauer

CoNe Freiburg

IIF INSTITUT FÜR INFORMATIK FREIBURG

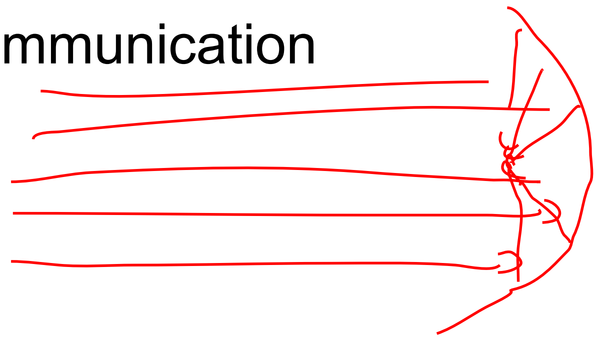
Multiple Use of the Medium

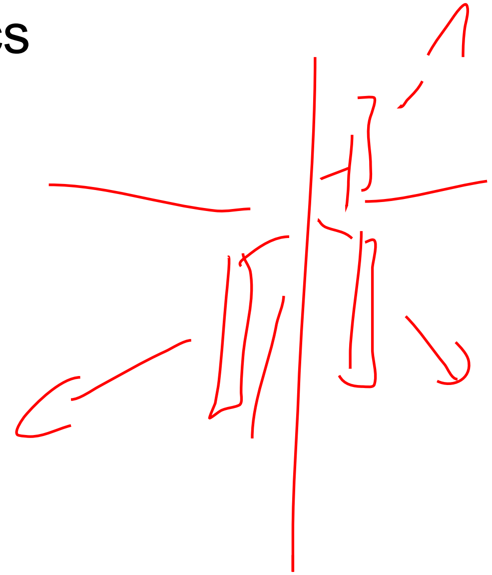
- **Spatial Multiplexing**
  - Parallel and exclusive use of transmission channels
    - e.g. Extra lines / cells / directional antenna
- **Frequency division multiplexing**
  - Multiple signals to be transmitted in a frequency range of bundled;
  - In radio transmission, different frequencies are assigned to different stations.
- **Time division multiplexing**
  - Delayed transmission of multiple signals
- **Code division multiplexing**
  - Coding of the signal into orthogonal codes, which can now be broadcast simultaneously on one frequency
  - Decoding with overlay also possible
- **Multiple-Input Multiple-Output**
  - Sending and receiving antennas by several
  - Using the spatial and temporal information about location of several waves
    - e.g. 802.11n

→ Polarization

Space

- **Spatial distribution (space multiplexing)**
  - Utilization of distance loss for the parallel operation of different radio cells → cellular networks
  - Using directional antennas for communications directed requested
  - GSM antennas with directional characteristics
  - Radio with a satellite dish
  - laser communications
  - infrared communication





Frequency Multiplexing

Bluetooth 79

- **Allocation of bandwidth in frequency sections**
- **Spread of the channels and hopping**
  - Direct Sequence Spread Spectrum (DSSS)
  - Xor a signal with a pseudo-random number sequence at the transmitter and receiver (Relates to code-division multiplexing)
  - Other signals appear as background noise
- **Frequency Hopping Spread Spectrum (FHSS)**
  - Frequency change by pseudo-random numbers
  - two versions
    - Quick change (almost hopping): Multiple frequencies per user data bits
    - Slowly changing (slow hopping): Multiple user bits per frequency

Time Multiplexing

- **Temporal distribution of sender-/receiver channel**
- **Participants receive exclusive periods (slots) on the media**
- **Accurate synchronization necessary**
- **Coordination necessary, or rigid division**

Direct Sequence Spread Spectrum

- **A chip is a bit sequence (given by {-1, +1}), which encode a smaller set of symbols**
- **E.g. Transmission signal: 0 = (+1,+1,-1), 1=(-1,-1,+1)**

0	1	0	1
+1 +1 -1	-1 +1+1	+1 +1 -1	-1 -1 +1

- **Coding by calculating the inner product c_i s_i of the received signal and the chip $c_0 = - c_1$:**

$$\sum_{i=1}^{m} c_{0,i} s_i \qquad \sum_{i=1}^{m} c_{1,i} s_i$$

- **In the case of a superimposed signal, the original signal can be decoded by filter**
- **DSSS is used by GPS, WLAN, UMTS, ZigBee, Wireless USB based on the Barker code**
  - Here for all v<m

$$\left| \sum_{i=1}^{N-v} a_i a_{i+v} \right| \leq 1$$

- Barker Code für 11Bit: +1 +1 +1 –1 –1 –1 +1 –1 –1 +1 –1

Code Division Multiple Access (CDMA)

- **CDMA (Code Division Multiple Access)**
  - e.g. GSM (Global System for Mobile Communication)
  - or UMTS (Universal Mobile Telecommunications System)
- **Uses chip-sequence with**
  - $C_i \in \{-1,+1\}^m$
  - $-C_i = (-C_{i,1}, -C_{i,2}, \ldots, -C_{i,m})$
- **so that the normalized inner product for all i ≠ j the result is 0.**

$$C_i \bullet C_j = \frac{1}{m} C_i \cdot (C_j)^T = \frac{1}{m} \sum_{k=1}^{m} C_{i,k} C_{j,k} = 0 \ .$$

- **Synchronized recipients get a linear combination of A and B**
- **Multiplying by the desired chip sequence yields the desired message.**

CDMA: Example 1

- **Sender A:**
  - 0 = (-1,-1)
  - 1 = (+1,+1)
- **Sender B:**
  - 0 = (-1,+1)
  - 1 = (+1,-1)
- **A sends 0, B sends 0:**
  - Result: (-2,0)
- **C receives (-2,0):**
  - Decoding of A: (-2,0) • (-1,-1) = (-2)(-1) + 0(-1) = 2
  - A has therefor sent 0 because result is positive

CDMA: Example 2

- **Sample-code:**
  - Code C_A = (+1,+1,+1,+1)
  - Code C_B = (+1,+1,-1,-1)
  - Code C_C = (+1,-1,+1,-1)
- **A sends Bit 0, B sends Bit 1, C sends nothing**
  - $V = C_1 + (-C_2) = (0,0,2,2)$
- **Decoding for A: $V \bullet C_1 = (0,0,2,2) \bullet (+1,+1,+1,+1) = 4/4 = 1$**
  - results in Bit 0
- **Decoding for B: $V \bullet C_2 = (0,0,2,2) \bullet (+1,+1,-1,-1) = -4/4 = -1$**
  - results in Bit 1
- **Decoding for C: $V \bullet C_3 = (0,0,2,2) \bullet (+1,-1,+1,-1) = 0$**
  - results in: no Signal.

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